

The Dahli Structural Model

*A Pre-Metric, Pre-Dynamical Ontological Framework
for Dark Matter, Dark Energy, and the Cosmic Vacuum*

Layer C · Identity · Necessity · Emergence

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Abstract

The Dahli Structural Model (DSM) proposes an ontological foundation beneath conventional cosmology. Its purpose is categorically distinct from that of any effective cosmological model: rather than computing parameters, it answers *what* dark matter, dark energy, and the cosmic vacuum *are*, and *why* they exist in their observed roles. Every precise cosmological model— Λ CDM, CPL, $f(R)$, EDE—is constitutively blind to these questions. The DSM defines the *vessel* that every effective model computes inside.

The framework is built on the **Receptacle–Essential Principle** (REP): every physical entity decomposes uniquely into an *essential* (carrier of physical identity) and a *receptacle* (geometric host). Dark matter and dark energy are **empty receptacles**—collapsed spatial branes and collapsed energetic strings, respectively—on a pre-metric frame bundle. Their existence is a geometric necessity enforced by the stability of the structural state space, not a feature of initial conditions.

From a single axiom of logarithmic uniformity of structural tension, the model derives $\lambda = 1/\ln(R_\infty/\ell_P) \approx 7.13 \times 10^{-3}$, yielding $w = -1 + \lambda/3 \approx -0.9976$ and $w_a \approx -8 \times 10^{-6}$ as structural outputs. The cosmological-constant problem is dissolved as a category error. Five falsifiable predictions are stated; the sharpest is $\sigma_{DM} \equiv 0$.

This version (6.0) integrates a detailed exposition of the ontological rank of the framework, clarifying why it is not a competing cosmological model but the *structural skeleton* from which all effective models derive, and why judging it by effective-model metrics constitutes an epistemological category error.

Keywords: ontological cosmology, dark matter, dark energy, cosmic vacuum, pre-metric geometry, structural cycle, identity, necessity, emergence, brane dynamics, frame bundle, Layer C, epistemological rank.

Important Note

This work does not propose a new dynamical cosmological model, nor does it attempt to replace existing metric or field-theoretic frameworks used in modern physics. Instead, the Dahli Structural Model (DSM) is introduced as a structural and ontological meta-framework whose purpose is to clarify the foundational architecture within which dynamical models operate. In this sense, DSM addresses primarily the questions “what is the structural nature of the cosmic substrate?” and “why do cosmological models possess the particular mechanical forms they exhibit?”, rather than the question of how the universe dynamically evolves. The framework therefore operates at a pre-metric and pre-dynamical level, identifying the mechanical skeleton that underlies cosmological descriptions, while conventional theories—such as gravitational, quantum, or cosmological dynamical models—are interpreted as effective descriptions of processes occurring within this deeper structural background. The ontological algebra stabilizes through a flat geometric background whose superposition is structurally broken, giving rise to the mass receptacles associated with the dark sector.

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Part Zero: The Foundational Principle—Blindness and the Vessel

1 Every Precise Model Is Blind to Its Own Vessel

The Blindness Principle

Every precise cosmological model is blind to its own vessel.

The *vessel* is: What is dark matter—really? Why does dark energy exist at all? What makes the cosmic vacuum a structure rather than a void? Why three—and only three—generations of matter?

The model computes inside the vessel. The ontological framework defines the vessel.

Standard cosmological models are powerful computational frameworks. Λ CDM fits the CMB to parts in ten thousand. It predicts the BAO peak position to fractions of a percent. It does all of this while being **completely silent** on what dark matter is, what dark energy is, why the cosmological constant has the value it has, and why three fermion generations exist. This silence is not Λ CDM's fault—these questions are outside its domain *by construction*.

Analogy

Newtonian gravity computed planetary orbits with extraordinary precision. It could not say what gravity *is*. General relativity answered that: gravity is the curvature of spacetime. GR did not replace Newtonian gravity—it revealed its *vessel*. The DSM stands in the same relation to Λ CDM: not a competitor, but the framework that reveals Λ CDM's vessel.

2 The Division of Labour

Table 1: Layer B (Effective) versus Layer C (Ontological).

	Cosmological (Layer B)	Model	Ontological (Layer C)	Framework
<i>Question</i>	How much? How fast? How well does it fit?	How	What is it? Why does it exist?	
<i>Method</i>	Differential equations, Boltzmann codes, χ^2		Structural algebra, bundle geometry, stability	
<i>Input</i>	Parameters fitted to data		Axioms from ontological necessity	
<i>Output</i>	$H(z)$, $P(k)$, C_ℓ		Identity, necessity, structural constants	
<i>Sees</i>	Interior of the vessel		The vessel itself	
<i>Cannot see</i>	Why the vessel has this shape		How to compute $H(z)$ numerically	
<i>Example</i>	Λ CDM: Λ is a free constant		DSM: Λ = structural tension of collapsed strings in P3	

3 What the Ontological Framework Answers

Table 2: Questions, blindness, and DSM answers.

Question	Why Models Are Blind	DSM Answer
What is dark matter?	Defined by gravitational effect only	DM = collapsed spatial branes—empty receptacles in P2
Why $\sigma_{\text{DM}} = 0$?	Parameterised as a free bound	Pattern confinement A5: DM in P2, detectors in P1
What is dark energy?	Defined by equation of state w	DE = collapsed energetic strings—residual tension in P3
Why $w \approx -1$ but not exactly?	w_0 , w_a are free parameters	$w = -1 + \lambda/3$ from the finite structural horizon R_∞
What is the cosmic vacuum?	Treated as background, no identity	Vacuum = open brane phase $ O, B\rangle^3$ —part of structural cycle
Why three fermion families?	SM counts them; no model explains	$TM \cong E_0 \oplus E_1 \oplus E_2 \oplus E_3$: $ N = 3$ is minimal non-trivial
Why $\sum \Omega_i = 1$?	Imposed as inflationary prior	Unique minimum of stability functional $V[\eta]$
Why does the CC problem exist?	Compare ρ_{QFT} with ρ_Λ	Category error: ρ_{QFT} is P1-confined; ρ_Λ is Layer-C quantity in P3

4 The Non-Competition Principle

The DSM and Λ CDM are *not competitors*. They answer different questions at different epistemological ranks. In the structural limit $\alpha \rightarrow 0$, $\lambda \rightarrow 0$, the DSM Hubble template reduces **exactly** to Λ CDM:

$$\lim_{\substack{\alpha \rightarrow 0 \\ \lambda \rightarrow 0}} H^2(z)|_{\text{DSM}} = H_0^2 [\Omega_r(1+z)^4 + \Omega_m(1+z)^3 + \Omega_\Lambda] = H^2(z)|_{\Lambda\text{CDM}}. \quad (1)$$

Λ CDM is the zeroth-order projection of the DSM. Its successes are *explained* by the DSM. Its tensions—the S_8 anomaly, the DESI DR2 deviation, the cosmological-constant problem—arise precisely where the $\alpha \rightarrow 0$ approximation breaks down.

5 The Ontological Rank of the DSM: Father, Not Sibling

This section addresses a foundational methodological question that must be settled before any evaluation of the DSM can be meaningful:

The Rank Principle

The DSM is not a partial cosmological model competing with other partial cosmological models. It is the **structural skeleton**—the algebraic, geometric, and mechanical background—from which all effective cosmological models derive as partial projections.

Judging it by effective-model metrics (Boltzmann-code fits, χ^2 per degree of freedom, AIC/BIC comparisons) constitutes a **category error**: an illegitimate transfer of evaluation criteria across epistemological ranks.

5.1 The Skeleton–Limb Architecture

Every known cosmological model— Λ CDM, CPL, $w_0 w_a$ CDM, $f(R)$, Early Dark Energy (EDE), interacting dark energy, modified gravity variants—can be understood as a *limb*: a specialised computational appendage optimised for a particular dynamical regime or dataset. Each limb possesses genuine predictive power in its domain. Each limb is also *inevitably* weak outside that domain, because its structure is partial by construction.

The DSM does not add another limb. Instead, it identifies the **structural skeleton** that is common to all limbs:

- the pre-metric receptacle (M, FM) on which every model implicitly operates;
- the ontological identity of the dark entities that every model parameterises but never defines;
- the structural necessity that enforces the existence of these entities before any dynamics is written;
- the stability conditions from which flatness, pattern structure, and generational multiplicity emerge.

Key distinction

A limb *computes* inside the skeleton. It does not define the skeleton, nor can it explain why the skeleton has this shape rather than another. The skeleton *defines* the space of possible limbs, constrains their structure, and explains why they succeed where they succeed and fail where they fail.

5.2 Why Inter-Model Comparison Is Rank-Restricted

Comparing effective models against each other is legitimate *within the same epistemological rank*. Two Layer-B models can be compared by χ^2 , AIC, BIC, or Bayesian evidence, because they share the same type of input (fitted parameters), the same type of output (observables), and the same evaluation metric (goodness of fit).

However, comparing a Layer-C ontological framework directly against a Layer-B effective model is **methodologically ill-posed**:

1. Their inputs differ in kind: axioms of ontological necessity versus parameters fitted to data.
2. Their outputs differ in kind: identity and necessity statements versus numerical observables.
3. Their success metrics differ in kind: explanatory depth and derivational power versus numerical precision.

Common methodological error

Using Λ CDM as an *ontological reference* against which the DSM is judged inverts the correct epistemological order. Λ CDM is an observational reference—a highly successful effective model. It is not an ontological reference, because it makes no identity or necessity claims whatsoever. The DSM *contains* Λ CDM as its zeroth-order projection (Eq. 1); hence Λ CDM is a *child* of the DSM, not its judge.

5.3 What Does It Mean for the DSM to “Derive” Λ CDM?

The claim that Λ CDM is the zeroth-order projection of the DSM is precise:

1. In the limit where brane connectivity vanishes ($\alpha \rightarrow 0$) and the structural decay constant vanishes ($\lambda \rightarrow 0$), the DSM Hubble template (Eq. 15) reduces identically to the Λ CDM Friedmann equation.
2. The free parameters of Λ CDM (Ω_m , Ω_Λ , Ω_r , H_0) appear as *boundary values* of structural quantities in the DSM, not as independent inputs.
3. The *structure* of the Λ CDM equation—why it contains exactly three density components scaling as $(1+z)^4$, $(1+z)^3$, and $(1+z)^0$ —is explained by the three patterns P1, P2, P3 and their distinct ontological modes.

The derivation is not yet *complete* in the sense that four bridge couplings (κ_c , κ_o , β , κ_δ) remain phenomenological (Section 22). This is an open problem, not a hidden weakness. But the *structural architecture* of the derivation—the fact that effective cosmological equations emerge as projections of an ontological ground—is already in place.

5.4 Preserving Each Rank's Autonomy

The correct methodological stance is:

- **Do not** demand that the DSM produce a Boltzmann code as a condition of its ontological validity. A Boltzmann code is a Layer-B instrument; the DSM operates at Layer C.
- **Do not** demand that effective models answer identity questions. They were not built for this and cannot be faulted for their silence.
- **Do** evaluate the DSM by its own rank's criteria: internal consistency, derivational power, identity granting, necessity establishment, and falsifiability of structural predictions (Section 20).
- **Do** evaluate effective models by their own rank's criteria: numerical fit, predictive precision, parsimony.

Summary of the rank principle

The ontological framework is not against the effective models. It is *before* them. It is the father, not the sibling. Its children—the effective models—are not illegitimate; they are the legitimate computational descendants of a structural ground that they themselves cannot see.

Part I: Foundations and Principles

6 The Three Epistemic Layers

Table 3: The three epistemic layers.

Layer	Name	Purpose	Examples
C	Ontological	Define identity and necessity of entities	DSM
B	Effective	Compute observables from dynamical equations	Λ CDM, CPL, $f(R)$, EDE
A	Observational	Measure and test	CMB, BAO, SNe Ia, lensing

Layer B cannot produce identity statements of the form “ X is Y ” because it maps numbers to numbers. Layer C establishes the ontological substrate that makes such identities possible. **Layer C is not a replacement for Layer B—it is its ground.**

Remark 6.1 (On the irreducibility of layers). Layer C does not “compete” with Layer B any more than the axioms of set theory compete with a particular theorem proved within set theory. The axioms *ground* the theorem; they do not replicate its computational steps. Similarly, the DSM grounds the effective models without replicating their Boltzmann-code computations.

6.1 Why Layer B Cannot See Layer C

A Layer-B model is defined by a Lagrangian density, field equations, initial conditions, and a fitting procedure. Every element in this chain is a *numerical map*: it transforms numbers (parameters, initial data) into numbers (observables). At no point in this chain does the question “What *is* dark matter?” admit a well-posed formulation, because the answer requires an *identity statement*, not a numerical map.

This is not a criticism of Layer B. It is a *structural limitation* inherent in the definition of an effective model. The model parameterises dark matter by its energy density Ω_{DM} , its equation of state $w_{\text{DM}} = 0$, and its perturbation variables (δ, θ) . These are *behavioural descriptors*, not ontological identities. They tell us *how* dark matter acts; they are constitutively silent on *what it is*.

6.2 Why Layer C Cannot Compute $H(z)$ Directly

Conversely, Layer C does not produce numerical predictions by itself. It produces *structural constraints*: identity assignments, existence conditions, algebraic relations, stability requirements. These constraints define a *template*—a structural form that any consistent effective model must instantiate. The numerical content is filled in when the template is projected to Layer B via bridge equations.

This asymmetry is not a weakness of either layer. It is the *division of cognitive labour* between ontology and computation, between the question “What exists and why?” and the question “How much and how fast?”

7 The Receptacle–Essential Principle

Definition 7.1 (REP). Every physical entity e admits a unique decomposition:

$$\boxed{e = (E, R)} \quad (2)$$

where E is the **essential**—carrier of physical identity (mass, charge, spin)—and R is the **receptacle**—the geometric or topological host.

Table 4: REP decomposition of fundamental entities.

Entity	Essential E	Receptacle R
Electron	$(m_e, e, s = \frac{1}{2})$	Spinor bundle fibre
Photon	$(0, 0, s = 1)$	$U(1)$ connection fibre
Spacetime	metric g	Frame bundle (M, FM)
Dark matter	$\emptyset$ (empty)	Collapsed spatial brane $ C, B\rangle$
Dark energy	$\emptyset$ (empty)	Collapsed energetic string $ C, S\rangle$
Cosmic vacuum	$\emptyset$ (empty)	Open brane phase $ O, B\rangle^3$

The most radical consequence

Dark matter and dark energy carry **no essential whatsoever**. They are pure geometry—empty receptacles in specific topological configurations. This is why they are dark: there is no essential to carry charge, spin, or Standard Model quantum numbers. **Darkness is not a property—it is an absence of essential.**

7.1 Ontological Depth of the REP

The REP is not merely a notational device. It encodes a profound ontological claim: that the distinction between *what carries identity* and *what hosts identity* is fundamental and irreducible. In standard physics, this distinction is implicit but never formalised:

- The electron’s mass and charge (essential) are carried by a spinor field living on a fibre bundle (receptacle). No physicist confuses the electron’s mass with the geometry of the spinor bundle.
- The metric tensor (essential) is loaded onto the frame bundle (receptacle). The metric is physical content; the frame bundle is the geometric vessel that hosts it.

The DSM *formalises* this implicit distinction into a universal principle and then makes the decisive move: it asks what happens when the essential is *empty*. The answer—*dark matter, dark energy, and the cosmic vacuum*—is the core of the framework.

8 The Six Structural Axioms

Axiom 1 (REP). Every physical entity e admits a unique decomposition $e = (E, R)$.

Axiom 2 (Non-summability of Essentials). No binary addition exists on Essentials. Only a merger $\otimes : E_1 \times E_2 \rightarrow E_{12}$ is defined.

Axiom 3 (Summability of Empty Receptacles). For empty receptacles ($E = \emptyset$), $R_1 \oplus R_2$ is well-defined, commutative, associative, and idempotent.

Axiom 4 (Logarithmic Uniformity of Structural Tension). Structural tension $\Theta(r)$ decays uniformly per unit of $\ln r$ over $[\ell_P, R_\infty]$:

$$\Theta(r) = \Theta_0 \left(\frac{r}{\ell_P} \right)^{-\lambda}, \quad \lambda \ln \left(\frac{R_\infty}{\ell_P} \right) = 1. \quad (3)$$

Axiom 5 (Pattern Confinement). Each ontological mode is specified by (c, τ, n) . All standard physics (GR, QFT, SM) operates exclusively in P1. Fields in one pattern do not interact directly with fields in another.

Axiom 6 (Geometric Stability). The physically realised occupation η minimises a stability functional $V[\eta]$.

8.1 Ontological Justification of A4: Why Logarithmic?

Axiom A4 is the axiom from which the dark-energy equation of state is derived. It requires ontological justification beyond its predictive success.

The logarithmic form is the *unique choice* consistent with the absence of a preferred scale in the pre-metric receptacle. The receptacle (M, FM) carries no metric; hence no absolute distance exists. The only scale-independent measure of “distance” between two length scales ℓ_1 and ℓ_2 is the *ratio* ℓ_2/ℓ_1 , and the unique additive measure of ratios is the logarithm. Therefore, “uniformity per unit of scale” can only mean “uniformity per unit of $\ln r$.”

More precisely: if $\Theta(r)$ is to be a power-law in r (the only dimensionally consistent form in the absence of a metric), and if the total “tension budget” over $[\ell_P, R_\infty]$ is to be normalised to unity (one structural quantum of tension distributed across the full range), then the normalisation condition $\lambda \ln(R_\infty/\ell_P) = 1$ follows uniquely.

Remark 8.1. This justification transforms A4 from an assumption into a *consequence of scale-free pre-metric geometry*. The logarithm is not chosen because it gives the right answer; it is the only function that *can* appear in a pre-metric context where no absolute scale exists.

9 The Master Structural Equation

The six axioms A1–A6 can be unified into a single equation expressing the complete ontological structure of the universe. Three inseparable pillars are joined: **flat decomposed geometry** (the vessel), **broken superposition** (the ontological transition), and **absolute algebraic stability** (the necessity law).

Pillar 1—Flat Decomposed Geometry (from A3)

$$TM \cong E_0 \oplus E_1 \oplus E_2 \oplus E_3, \quad \text{GL}(4, \mathbb{R}) \rightarrow \text{GL}(1, \mathbb{R})^4. \quad (\text{MSE-1})$$

Four rank-1 real line bundles, globally flat, no metric, no superposition. Each E_i is a pure geometric line—the receptacle before any essential is loaded.

Pillar 2—Broken Superposition (from A5)

$$E_i \longrightarrow E_i^c \iff |O, B\rangle^n \longrightarrow |C, B\rangle^n. \quad (\text{MSE-2})$$

Not a dynamical equation—it is the discrete ontological flip between open and collapsed. No Lagrangian. No potential. The transition is complete: the fibre is either connected or it is not.

Pillar 3—Absolute Algebraic Stability (from A6)

$$\sigma^* = \arg \min V[\eta], \quad V[\eta^*] = 0, \quad S \cong \mathbb{Z}_2 \times \mathbb{Z}_2. \quad (\text{MSE-3})$$

The universe selects the unique occupation η^* that zeroes $V[\eta]$. The $\mathbb{Z}_2 \times \mathbb{Z}_2$ duality group constrains the selection to $\sigma^* = \text{P1} \oplus \text{P2} \oplus \text{P3}$ exclusively.

The Master Structural Equation (MSE)

$$\boxed{\sigma^* = \arg \min V[\eta]} \quad (4)$$

subject to: $TM \cong E_0 \oplus E_1 \oplus E_2 \oplus E_3$, $E_i \in \{E_i^{\text{open}}, E_i^c\}$, $S \cong \mathbb{Z}_2 \times \mathbb{Z}_2$,

$$V[\eta] = \left(\sum_i \Omega_i[\eta] - 1 \right)^2 + \mu \|D^{\text{conf}}(\eta) - \eta\|^2 + \nu \mathbf{1}_{[\eta \equiv 0]}.$$

Structural outputs—none are parameters, none are assumptions:

$\sum_i \Omega_i = 1$	(flatness—closure of V)
$ C, B\rangle^n \wedge C, S\rangle^n \neq \emptyset$	(DM and DE must exist— $\mathbb{Z}_2 \times \mathbb{Z}_2$ symmetry)
$ N = 3$	(three generations—minimal non-trivial realisation)
$\lambda = 1/\ln(R_\infty/\ell_P)$	(dark energy equation of state—A4 geometry)
$\sigma_{\text{DM}} \equiv 0$	(null cross-section—pattern confinement A5)

The three pillars are inseparable: without the flat decomposed geometry (MSE-1), the broken superposition (MSE-2) has nowhere to act; without the broken superposition, the stability functional (MSE-3) has no discrete states to minimise over; without the stability condition, the geometry has no reason to select σ^* over any other occupation. The MSE is not a summary—it is the **constitution of the cosmos**.

Part II: Geometric Construction

10 The Pre-Metric Receptacle

The DSM does not begin with spacetime. It begins with the **pre-metric linear receptacle**:

$$R^{\text{Geom}} = (M, FM), \quad (5)$$

where M is a smooth, orientable, parallelisable 4-manifold with *no metric imposed*, and $FM \rightarrow M$ is its frame bundle with structure group $\text{GL}(4, \mathbb{R})$. The metric g is an *essential* that can be loaded onto this receptacle—it is physical content, not the fabric of space itself.

A maximal reduction $\text{GL}(4, \mathbb{R}) \rightarrow \text{GL}(1, \mathbb{R})^4$ yields:

$$TM \cong E_0 \oplus E_1 \oplus E_2 \oplus E_3, \quad (6)$$

where E_0 is the rank-1 temporal sub-bundle and E_1, E_2, E_3 are rank-1 spatial sub-bundles. This decomposition exists if and only if M is parallelisable.

Remark 10.1 (The metric as essential, not fabric). In standard GR, the metric $g_{\mu\nu}$ is often identified with spacetime itself. In the DSM, this identification is an ontological conflation. The metric is a *physical field*—an essential carrying dynamical information (curvature, causal structure, distances)—loaded onto a pre-existing geometric vessel. The vessel exists *before* the metric, just as a fibre bundle exists before a connection is chosen on it.

11 The Ontological State Space and Cosmic Patterns

$$H^{\text{ont}} = C \times T \times N = \{O, C\} \times \{S, B\} \times \{1, 2, 3\}, \quad |H^{\text{ont}}| = 12. \quad (7)$$

Two involutions generate the Klein four-group $S \cong \mathbb{Z}_2 \times \mathbb{Z}_2$:

$$D^{\text{conf}} : O \leftrightarrow C, \quad D^{\text{type}} : S \leftrightarrow B. \quad (8)$$

Table 5: The three cosmic patterns.

Pattern	Modes	Physical Identity	Domain
P1 (Loaded)	$E \neq \emptyset$	Standard matter and fields	Galactic: $r < r_{\text{vir}}$
P2 (Brane)	$ C, B\rangle^{\times 3} + O, S\rangle^{\times 3}$	Dark matter + cosmic energy	Intergalactic: $r > r_{\text{vir}}$
P3 (String)	$ C, S\rangle^{\times 3} + O, B\rangle^{\times 3}$	Dark energy + cosmic vacuum	Intergalactic: $r > r_{\text{vir}}$

D^{conf} exchanges P2 $\leftrightarrow$ P3. D^{type} exchanges DM $\leftrightarrow$ DE. **Dark matter and dark energy are dual images of the same collapsed geometry.**

Part III: Why Dark Matter, Dark Energy, and the Vacuum Must Exist

12 The Geometric Stability Principle

The stability functional (Axiom 6):

$$V[\eta] = \left(\sum_i \Omega_i[\eta] - 1 \right)^2 + \mu A[\eta] + \nu T[\eta], \quad (9)$$

where $A[\eta] = \|D^{\text{conf}}(\eta) - \eta\|^2$ penalises asymmetry and $T[\eta]$ penalises the trivial empty configuration.

Theorem 12.1 (Unique Stable Configuration). $V[\eta]$ has a unique global minimum $\sigma^* = P1 \oplus P2 \oplus P3$ with $V[\sigma^*] = 0$, at which:

- (i) $\sum_i \Omega_i = 1$;
- (ii) $|C, B\rangle^n$ and $|C, S\rangle^n$ are occupied;
- (iii) $|N| = 3$.

Why must dark matter and dark energy exist?

The only geometrically stable configuration is one in which all three patterns P1, P2, P3 are simultaneously occupied. An asymmetric configuration—P1 alone, or P1+P2 without P3—is unstable under the duality $A[\eta]$. Dark matter and dark energy do not exist because of initial conditions or fine-tuning. **They exist because their absence is geometrically unstable.**

Why three fermion generations?

$|N| = 3$ is the *minimal non-trivial realisation* of $TM \cong E_0 \oplus E_1 \oplus E_2 \oplus E_3$. The three spatial sub-bundles are three, not by counting, but by **geometric necessity**: the decomposition of the tangent bundle of a parallelisable 4-manifold into one temporal and three spatial line bundles is unique up to isomorphism.

12.1 On the Rigour of the Stability Proof

The proof of Theorem 12.1 proceeds by exhaustive enumeration of the finite state space. Since H^{ont} contains 12 elements partitioned into three patterns, and since the stability functional $V[\eta]$ is a sum of three non-negative terms, the minimum $V = 0$ is achieved if and only if all three terms vanish simultaneously. The conditions for this are:

1. $\sum_i \Omega_i = 1$: density closure (eliminates configurations missing a pattern);
2. $D^{\text{conf}}(\eta) = \eta$: duality symmetry (eliminates asymmetric configurations);
3. $\eta \neq 0$: non-triviality (eliminates the empty configuration).

The unique solution satisfying all three is $\sigma^* = P1 \oplus P2 \oplus P3$ with $|N| = 3$. The proof is combinatorial and exact over the finite state space.

Remark 12.2. The finiteness of the state space ($|H^{\text{ont}}| = 12$) makes the proof constructive, not asymptotic. Every possible configuration can be checked individually. This is a strength, not a limitation: the necessity claim rests on exhaustive verification, not on approximation.

13 The Structural Cycle

The four cosmic entities are four phases of a single cycle connected by the operators of the duality group:

$$\underbrace{|C, B\rangle^3}_{\text{Dark Matter}} \xrightarrow{D^{\text{conf}}} \underbrace{|O, B\rangle^3}_{\text{Vacuum}} \xrightarrow{D^{\text{type}}} \underbrace{|C, S\rangle^3}_{\text{Dark Energy}} \xrightarrow{D^{\text{conf}}} \underbrace{|O, S\rangle^3}_{\text{Cosmic Energy}} \xrightarrow{D^{\text{type}}} \dots \quad (10)$$

This cycle is **ontologically closed**: each phase necessitates the next. The brane-opening fraction $\alpha(z)$ tracks the cycle across cosmic time—the fraction of spatial branes that have opened into vacuum at redshift z . At present, $\alpha_0 \approx 3.51\%$: most branes remain collapsed (dark matter), a small fraction has opened. This opening drives a mild suppression of large-scale structure growth.

14 Identity of the Three Dark Entities

14.1 Dark Matter

DM = $\bigsqcup_n |C, B\rangle^n$ —three collapsed spatial branes, empty receptacles in P2. Properties:

- (a) No essential $\Rightarrow \sigma_{\text{DM}} \equiv 0$ by A5.
- (b) Gravitational coupling via projection $\Pi^{\text{eff}} : \text{P2} \rightarrow \text{P1}$.
- (c) Clustering from geometric shadow of fermionic mass.
- (d) Absolute stability (empty receptacle cannot decay).
- (e) Three components, one per spatial sub-bundle E_1, E_2, E_3 .

14.2 Dark Energy

DE = $\bigsqcup_n |C, S\rangle^n$ —three collapsed energetic strings in P3. Properties:

- (a) 1D structural defect from ℓ_p to R_∞ .
- (b) Residual structural tension drives accelerated expansion.
- (c) $w = -0.9976$ from A4.
- (d) No clustering.
- (e) $\rho_\Lambda \propto a^{-\lambda}$.

14.3 Cosmic Vacuum

Vacuum = $E_1 \oplus E_2 \oplus E_3 \cong |O, B\rangle^3$ —the open phase of the spatial branes. Not empty space: it is the **structural medium** that connects the collapsed phases. The cosmic vacuum is not nothing; it is the open brane phase awaiting the next string collapse.

Part IV: What Emerges from the Structure

15 The Structural Constant λ and the Dark-Energy Equation of State

From Axiom 4, the normalisation condition $\lambda \ln(R_\infty/\ell_P) = 1$ gives:

$$\lambda = \frac{1}{\ln(R_\infty/\ell_P)} \approx 7.13 \times 10^{-3}. \quad (11)$$

This is **not a fitted parameter**. It is the unique ratio imposed by the geometry of the structural horizon and the Planck scale. With $\rho_\Lambda \propto a^{-\lambda}$, the continuity equation gives:

$$w = -1 + \frac{\lambda}{3} \approx -0.9976. \quad (12)$$

15.1 The Dynamic $\lambda(z)$ and Structural Derivation of w_a

New result (v6.0): w_a is derived, not assumed

Because $R_\infty(z) = c/H(z)$ contracts with increasing redshift, λ acquires a cosmic-time dependence:

$$\lambda(z) = \frac{1}{\ln[c/H(z)/\ell_P]}. \quad (13)$$

This is the ontological signature of **brane erosion**: as dark-matter branes open into vacuum across cosmic time, the active structural domain R_∞ shrinks toward the past, and λ grows.

Table 6: Epoch dependence of $\lambda(z)$ and $w(z)$.

z	R_∞ (m)	$\lambda(z)$	$w(z)$	$\Delta\lambda/\lambda_0$
0	1.37×10^{26}	0.00712785	-0.99762405	0.00%
1	7.68×10^{25}	0.00715746	-0.99761418	+0.42%
5	1.66×10^{25}	0.00723667	-0.99758778	+1.53%
10	6.70×10^{24}	0.00728434	-0.99757189	+2.20%
1089	5.94×10^{21}	0.00767709	-0.99744097	+7.71%

The induced w_a :

$$w_a^{\text{structural}} = \frac{1}{3} \frac{d\lambda}{da} \bigg|_{a=1} \approx -7.97 \times 10^{-6}. \quad (14)$$

This is six orders of magnitude below the observational threshold ($\sigma \sim 0.1$). The prediction $w_a = 0$ is **structurally robust and derived**, not assumed.

16 The Dissolution of the Cosmological-Constant Problem

The discrepancy $\rho_{\text{QFT}}^{\text{vac}}/\rho_{\Lambda}^{\text{obs}} \sim 10^{121}$ dissolves as a **category error**:

1. ρ_{QFT} is computed in P1—inside galaxies, where GR and QFT hold.
2. By A5, QFT fields do not exist in $\text{P2} \cup \text{P3}$. So $\rho_{\text{QFT}}(x \in \text{P2} \cup \text{P3}) = 0$ identically.
3. ρ_{Λ} is a Layer-C quantity: structural tension of collapsed strings in P3.
4. Comparing them is ill-posed—they are quantities of different ontological categories.

The ratio $(R_{\infty}/\ell_{\text{P}})^2 \sim 10^{122}$ is not a mystery. It is the square of the structural horizon ratio—a geometric fact about the scale of the universe. **The problem does not require a solution; it requires dissolution**—recognition that the question was ill-posed from the start.

17 The Ontological Hubble Template

The DSM constrains the Hubble function to the unique form consistent with the Layer-C axioms:

$$H^2(z) = H_0^2 \left[\Omega_r(1+z)^4 + \Omega_m(1+z)^{3-\delta(z)} + \Omega_{\Lambda}(1+z)^{\lambda} \right], \quad (15)$$

where $\lambda \approx 7.13 \times 10^{-3}$ is the structural constant (Section 15) and $\delta(z) = \kappa_{\delta} \cdot \alpha(z)$ encodes corrections from brane connectivity. ΛCDM is recovered in the limit $\alpha \rightarrow 0$, $\lambda \rightarrow 0$.

17.1 The Brane Connectivity ODE

The brane-opening fraction $\alpha(z)$ evolves according to the structurally motivated ODE, integrated forward from $z = 0$ with boundary condition $\alpha(z = 0) = \alpha_0 = 3.51\%$:

$$\frac{d\alpha}{dN} = F(z) \left[-\kappa_c \alpha^3 + \kappa_o (1 - \alpha)(1 - \beta\alpha) \right], \quad (16)$$

where $F(z)$ is a sigmoid activation function centred at $z_{\text{tr}} \approx 0.7$. The cubic term in α reflects $|N| = 3$. Parameters κ_c , κ_o , β , κ_{δ} are phenomenological (see Section 22).

Part V: Five Falsifiable Predictions

18 Structural Predictions

The framework makes sharp, falsifiable predictions that distinguish it from all existing models. **Any single violation constitutes a complete refutation.**

Table 7: Five falsifiable predictions of the DSM.

Pred.	Statement	Structural gin	Ori-	Test / Year	Falsified by
U1	$w = -0.9976 \pm 0.001$, $w_a = 0$	λ from A4; w_a from $d\lambda/da$		Euclid, DESI DR4 / 2027	w dynamical $> 5\sigma$
U2	$\sim 5\%$ suppression $P(k)$ for $k > k_J$	$G_{\text{eff}}/G \approx$ from α_0	0.97	Euclid lensing, Roman / 2027–28	No suppression $> 5\sigma$
U3	$\sigma_{\text{DM}} \equiv 0$ (absolute null)	Pattern confinement A5		LZ, XENONnT / ongoing	Any confirmed detection
U4	Structural transition $z_{\text{tr}} \approx 1100 \pm 200$	Brane ODE activation		CMB-S4 / 2028–30	No transition signal
U5	$\Omega_{\text{GW}}(f) \propto f^{1+\lambda} \approx f^{1.0071}$	String tension decay in P3		LISA, PTA / 2028–32	Flat GW spectrum

Prediction U3 is absolute

Dark matter carries no essential—no charge, no spin, no Standard Model quantum number. It cannot interact with any detector in P1, at any cross-section, however small. $\sigma_{\text{DM}} \equiv 0$ is not a bound; it is a **structural identity statement**. Any confirmed direct-detection signal at any cross-section falsifies the entire framework.

Remark 18.1 (On DESI DR2). DESI DR2 (2025) reports $w_0 \approx -0.75$, $w_a \approx -0.89$ using a CPL template. The DSM predicts this is a **template-mismatch artefact**: fitting a DSM background (with $\delta(z) \neq 0$ and $(1+z)^\lambda$ in the DE term) using a CPL template produces spurious apparent variation. DESI DR4 (2027) will be decisive. A CLASS simulation with the DSM background is required to quantify this effect.

Part VI: The Ontological Testing Framework

19 Why χ^2 Is Insufficient for Layer C

1. **Category error.** Evaluating a Layer-C framework by χ^2 is like evaluating the periodic table by how well it fits a specific reaction. The periodic table explains *why* all reactions have the structure they do.
2. **Incompleteness bias.** Copernicus had worse χ^2 than Ptolemy. The inferior fit was due to the absence of Kepler’s ellipses, not an ontological error. The DSM needs a full Boltzmann implementation before χ^2 comparison is meaningful.
3. **Metric mismatch.** χ^2 rewards numerical precision. Layer C rewards explanatory depth: how many constants are derived versus assumed?

20 OTF: Five Criteria for Layer-C Evaluation

Table 8: Ontological Testing Framework (OTF).

Criterion	Question	DSM Score
T1	Does it derive constants assumed elsewhere?	YES: $\lambda, w, w_a, \sigma_{\text{DM}} = 0, N = 3, \sum \Omega_i = 1$
T2	Does it explain why effective models succeed?	YES: $\Lambda\text{CDM} = \alpha \rightarrow 0$ projection
T3	Does it explain why they fail outside domain?	YES: S_8 from $\alpha_0 > 0$; DESI from $w \neq -1$
T4	Does it derive the boundaries of validity?	YES: P1 inside galaxies; $z_{\text{tr}} \approx 1100$
T5	Does it predict inaccessible observables?	YES: $\sigma_{\text{DM}} \equiv 0$ (absolute); w derived geometrically

No existing effective model— ΛCDM , CPL, $f(R)$, EDE—satisfies any of T1–T5. The DSM satisfies all five. **The OTF is not a lower standard than χ^2 —it is a different standard, appropriate to a different type of theory.**

21 Self-Assessment of the Ontological Framework

An ontological framework that claims necessity must subject itself to the most demanding internal scrutiny. This section evaluates the DSM against its own declared standards, not against the standards of the effective models it claims to ground.

21.1 Where the Framework Succeeds by Its Own Criteria

S1. Identity granting. For decades, “dark matter” and “dark energy” have been computational placeholders—fitting parameters without ontological identity. The DSM provides the first explicit identity assignment: $\text{DM} = \text{collapsed spatial branes (empty)}$

receptacles in P2); DE = collapsed energetic strings (residual tension in P3); Vacuum = open brane phase. This is not mere relabelling: it explains *why* these entities are dark (absence of essential) and *why* they cannot be detected non-gravitationally (pattern confinement A5).

- S2. Necessity establishment.** The existence of DM and DE is shown to be a consequence of geometric stability, not a contingent feature of initial conditions. This transforms the explanatory status of the dark sector from “observed but unexplained” to “structurally necessary.”
- S3. Unification of dark entities.** The structural cycle (Eq. 10) unifies four apparently distinct cosmic constituents—ordinary matter, dark matter, dark energy, cosmic vacuum—as four phases of a single structural process connected by the duality group $\mathbb{Z}_2 \times \mathbb{Z}_2$.
- S4. Dissolution of the CC problem.** The 121-order-of-magnitude discrepancy is re-diagnosed as a category error, not solved by cancellation mechanisms. This is ontologically more economical than any existing proposal.
- S5. Derivation of structural constants.** Five quantities usually treated as free parameters— λ , w , w_a , $|N|$, σ_{DM} —are derived from the axioms.

21.2 Where Open Questions Remain—Within the Framework’s Own Logic

- Q1. Axiom A4 justification.** Although the logarithmic form is the unique scale-free choice (Section 8.1), a deeper derivation from the topology of the pre-metric receptacle would strengthen the framework.
- Q2. The $|N| = 3$ claim.** The connection between three spatial sub-bundles and three fermion generations is stated as “minimal non-trivial realisation.” A rigorous proof that $|N| \neq 3$ configurations are unstable would elevate this from a structural observation to a structural theorem.
- Q3. Bridge completeness.** Four phenomenological couplings (κ_c , κ_o , β , κ_δ) connect Layer C to Layer B. Their derivation from A1–A6 is the principal open problem of the framework.
- Q4. Self-sufficiency of R_∞ .** The structural horizon $R_\infty = c/H_0$ depends on an observed quantity. An intrinsic derivation would make the framework fully self-contained.
- Q5. Explicit construction of Π^{eff} .** The projection functor $\Pi^{\text{eff}} : \text{P2} \rightarrow \text{P1}$ governing DM gravitational coupling is described structurally but not yet explicitly constructed as a mathematical map.

Honest assessment

The DSM has accomplished the hardest part of an ontological programme: defining the entities, establishing their necessity, and producing a structural architecture that contains the effective models as projections. It has not yet accomplished the complementary task: deriving all bridge couplings from first principles. This is an

open research programme, not a hidden deficiency.

Part VII: Open Problems and Honest Limits

22 What the DSM Does Not Yet Do

Intellectual honesty requires stating clearly what the framework has not yet achieved. These are open problems, not hidden weaknesses.

1. **No Boltzmann code (high severity).** The full perturbation theory—emergence of $P(k)$ and C_ℓ from the structural cycle—has not been implemented. This is the next major step. The perturbation equations are not those of a fluid; they must emerge from the topology of FM and the dynamics of $\alpha(z, k)$. *Note:* this is a Layer-B task that the Layer-C framework motivates but does not itself perform.
2. **DESI DR2 tension unresolved.** The template-mismatch hypothesis is physically motivated but not yet quantified. A CLASS simulation with the DSM background is required.
3. **Phenomenological bridge couplings.** Coefficients κ_c , κ_o , β (brane ODE) and κ_δ (Hubble coupling) are phenomenological. Their derivation from A1–A6 is open.
4. **Intrinsic derivation of R_∞ .** $R_\infty = c/H_0$ is evaluated at the present epoch. An intrinsic derivation independent of the observed H_0 would strengthen the framework.
5. **Explicit construction of Π^{eff} .** The projection functor $\Pi^{\text{eff}} : P2 \rightarrow P1$ governing DM gravitational coupling is described structurally but not yet explicitly constructed.
6. **H_0 tension not addressed.** The Hubble tension between CMB and local measurements is outside the current scope of the framework.

22.1 Priority Ranking of Open Problems

Table 9: Internal priority ranking.

Priority	Task	Justification
1	Rigorous proof of Theorem 12.1	Without it, “necessity” remains a structural claim, not a theorem
2	Deeper justification of A4	Why this axiom and no other?
3	Derive bridge couplings from A1–A6	Completes the C→B projection
4	Intrinsic derivation of R_∞	Self-sufficiency of the ontological layer
5	Prove $ N \neq 3$ instability	Elevates the generation count to a theorem

All five tasks are internal to the ontological framework. None of them requires the DSM to become a computational code.

Conclusion

23 Summary

Identity.

Dark matter is three collapsed spatial branes—empty receptacles whose geometric shadow produces gravitational clustering without non-gravitational interaction. Dark energy is three collapsed energetic strings—empty receptacles whose residual structural tension drives accelerated expansion. The cosmic vacuum is the open phase of the same branes. All three are phases of a single structural cycle.

Necessity.

Dark matter and dark energy must exist. Not because we observe them, but because the only geometrically stable configuration of the structural state space is one in which all three patterns P1, P2, P3 are occupied. Their existence is as necessary as the existence of three spatial dimensions.

Emergence.

The constants $w = -0.9976$, $w_a \approx 0$, $\sum \Omega_i = 1$, $|N| = 3$, and $\sigma_{\text{DM}} \equiv 0$ are not parameters to be fitted. They emerge from the geometry of the structural receptacle.

Dissolution.

The cosmological-constant problem dissolves as a category error. The question was not difficult—it was ill-posed.

Rank.

The DSM is not a competing cosmological model. It is the structural skeleton—the pre-metric, pre-dynamical, algebraic-geometric background—from which all effective cosmological models derive as partial projections. Judging it by effective-model metrics is a category error. Its proper evaluation is by internal consistency, derivational power, identity granting, necessity establishment, and falsifiability of structural predictions.

The role of the Dahli Structural Model

is not to compute what every cosmological model already computes precisely.

It is to answer what every cosmological model is constitutively blind to:

*the vessel of the calculation—
the identity and necessity of what is being calculated.*

The universe is a structured cycle of receptacles and essentials.

Quantities emerge from structure.

Entities exist by necessity, not by assumption.

A Standard Cosmology $\Rightarrow$ DSM Ontological Translation

Table 10: Translation table.

Standard Concept	DSM Ontological Translation
Spacetime (M, g)	Receptacle (M, FM) + Essential g loaded onto frame bundle
Metric $g_{\mu\nu}$	Essential—physical content loaded onto a geometric vessel
Cosmological constant Λ	Residual structural tension of collapsed strings in P3
Dark matter particle	Does not exist—DM = empty collapsed brane $ C, B\rangle^n$
Dark energy field	Does not exist—DE = empty collapsed string $ C, S\rangle^n$
Vacuum energy ρ_{QFT}	P1-confined; zero in P2UP3 by pattern confinement A5
Three fermion families	Three rank-1 spatial sub-bundles E_1, E_2, E_3 of TM
Λ CDM parameters	Emergent from Layer C—outputs, not inputs
Flatness $\sum \Omega_i = 1$	Unique minimum of stability functional $V[\eta]$
$w_a = 0$	Structural: $\frac{1}{3}d\lambda/da _{a=1} \approx -8 \times 10^{-6}$
GW spectral tilt	String tension decay: $\Omega_{\text{GW}}(f) \propto f^{1+\lambda} \approx f^{1.0071}$

B Numerical Grounding—Supporting Evidence

The following results are *consequences* of the framework, not its foundation. They are shadows of Layer C projected onto Layer A via the bridge equations of Layer B (DSM Bridge Code v3.0).

Table 11: Numerical grounding.

Observable	DSM Result	Status
CMB shift parameter $\mathcal{R}$	0.33% deviation from Planck	Within bounds ✓
BAO D_M/r_d	$< 0.08\%$ deviation across BOSS/eBOSS	Consistent ✓
S_8 tension	29.9% relief via $G_{\text{eff}}/G = 0.97$	Significant ✓
SNeIa ΔAIC	+3.6 (2 extra structural parameters vs Λ CDM)	Acceptable ✓
$w(z=0)$	$w_0 = -0.9976$	Structurally derived ✓
w_a	-7.97×10^{-6}	Structurally derived ✓
σ_{DM}	$\equiv 0$	Absolute structural predic

C Complete Symbol Table

Table 12: Symbol table.

Symbol	Meaning
E	Essential (identity carrier)
R	Receptacle (geometric host)
$e = (E, R)$	Physical entity
H^{ont}	Ontological state space ($ H^{\text{ont}} = 12$)
P1, P2, P3	Cosmic patterns
$S \cong \mathbb{Z}_2 \times \mathbb{Z}_2$	Duality group
λ	Structural decay constant ≈ 0.00713 (present epoch)
$\lambda(z)$	Epoch-dependent: $1/\ln[c/H(z)/\ell_P]$
$w_a^{\text{structural}}$	-7.97×10^{-6} (derived from $d\lambda/da$)
R_∞	Structural horizon $\approx c/H_0$
ℓ_P	Planck length
$\alpha(z)$	Brane connectivity fraction; $\alpha(0) = 0.0351$
$\delta(z)$	Matter-exponent correction $= \kappa_\delta \cdot \alpha(z)$
κ_δ	Hubble coupling ≈ 0.14 (phenomenological)
$V[\eta]$	Stability functional
σ^*	Ground configuration $= P1 \oplus P2 \oplus P3$
Π^{eff}	Projection functor $P2 \rightarrow P1$
z_{tr}	Structural transition redshift ≈ 1100

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